Engineering of underground system configuration for Seasonal Thermal Energy Storage (STES) systems implementation to improve energy efficiency in existing buildings

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1. Introduction

Energy use in buildings accounts for approximately 40% of EU energy consumption. Energy efficiency in new buildings is important, but existing building stock is the main target. Existing buildings, indeed, are characterised by particular requirements and constraints that are not present in new buildings and that requires new developments and adaptation of existing technologies.

In order to fulfill the most recent EU directives, solutions for a drastic reduction in primary energy consumption are required. Space heating and Domestic Hot Water (DHW) represent the largest part of energy use in buildings nowadays, thus solar thermal energy seems to be one of the most promising heat source. At this purpose, the underground storage of solar thermal production is an interesting solution investigated by EINSTEIN, a research project co-funded by the European Commission within the Seventh Framework Programme (FP7) (2007-2013).

2. Stategic objectives

The overall objective of the EINSTEIN project is the development, evaluation and demonstration of a low energy heating system based on Seasonal Thermal Energy Storage (STES) concept in combination with Heat Pumps (HP) for space heating and DHW requirements for existing buildings to drastically reduce energy consumption; the primary energy savings is up to 70% compared to conventional existing thermal systems.

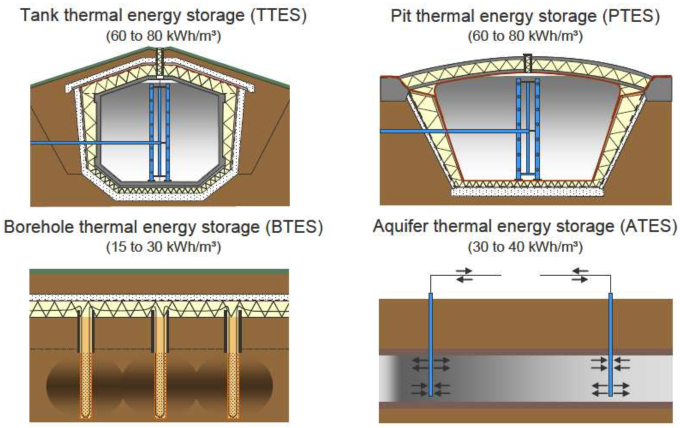

Fig. 1: Seasonal Thermal Energy Storage types of technologies

This goal will be achieved by:

- Technological developments for **STES systems adaptation for existing buildings** and integration with the built environment
- Development of a **novel, high-efficiency, cost-effective and compact heat pump** suitable for existing buildings and optimized for higher temperature heat sources such as STES systems
- Development of **new business and cost models** which consider **the entire life cycle of a building** and incorporate the benefits of reduced operating costs; **a decision support tool** will help the planners **to find the best technology** to install in each particular case
- Development of **integrated building concept**. As cost-effectiveness is one of the main aspects to be considered in building retrofitting, a methodology and a software tool for most cost-effective global energy intervention framework definition for building retrofitting will be developed
- Development of an **engineering system** for the **underground configuration** associated to the STES implementation

3. Results

Within the framework of EINSTEIN project, specific studies have been undertaken about the engineering of underground system configuration in order to identify the most appropriate method for implementing the piping network associated to the STES system.

At this purpose, trenchless technologies are particularly attractive construction solutions in urbanized area with heavy vehicular and pedestrian traffic and numerous existing underground utilities. The application of these technologies to district heating supply systems allows operating at lower levels underground, thus eliminating the issues that can arise from interferences with other urban networks already installed.

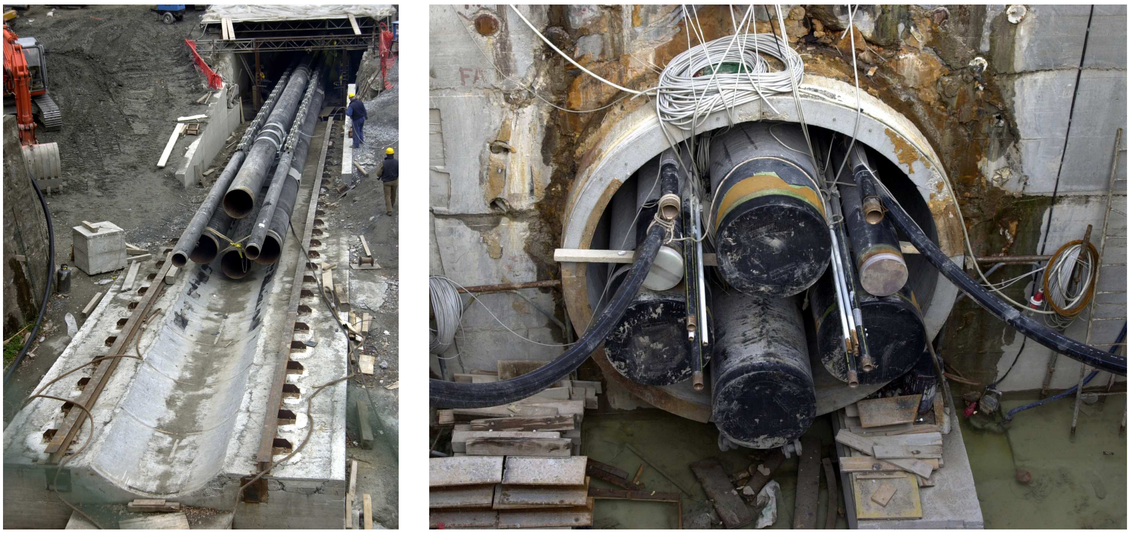

Fig. 2: Host pipe with multiple function

Their use allows besides inserting all the product pipes required for STES installation into a unique casing pipe. The **casing pipe** (or protection pipe or host pipe) provides the multiple functions of accepting the **product pipes** making easier their lay-down, protects them from external loads and, in case of failure, acts as a protective covering. In connection with trenchless methods, it serves as a mean to create and/or support the cavity within the subsoil; it must also be able to withstand the loads in the construction state.

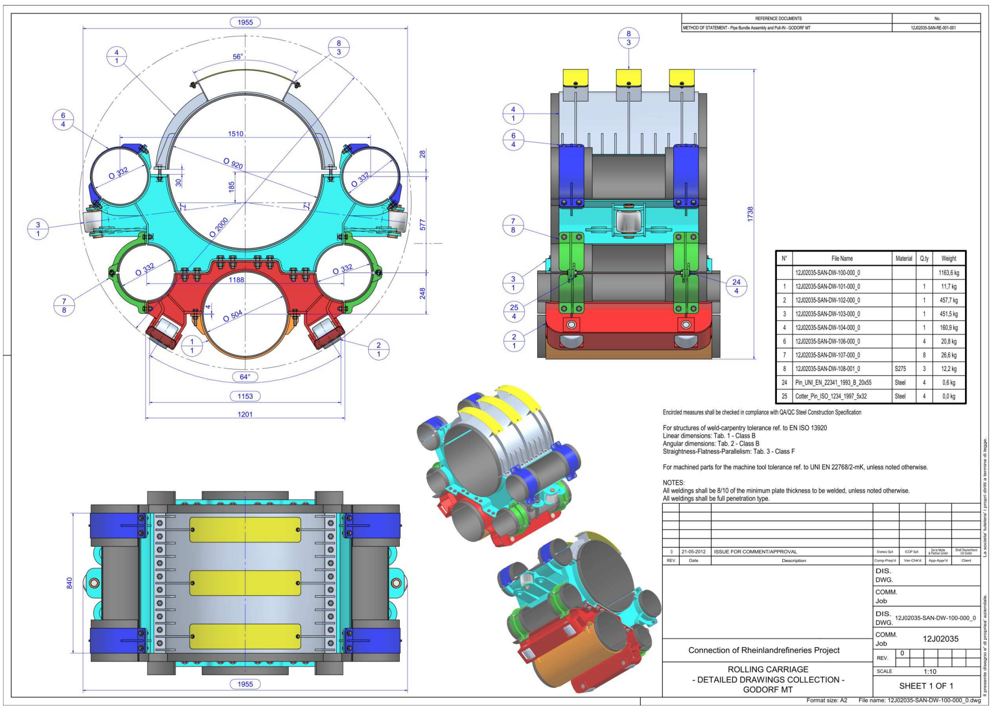

Fig. 3: Pipelines installations

An exhaustive analysis of the main trenchless technologies has been performed and the results focused the attention to three perforation methods:

MicroTunnelling (MT)

Microtunnelling is defined as a remotely-controlled, guided, pipe-jacking operation that provides continuous support to the excavation face by applying mechanical or fluid pressure to balance groundwater and earth pressures. It allows pipes to be automatically installed without digging open trenches and without employing manpower inside the tunnel. The full-face excavation is carried out by a cutter head (also called microtunneller) that is pushed into the ground together with the pipe to be installed.

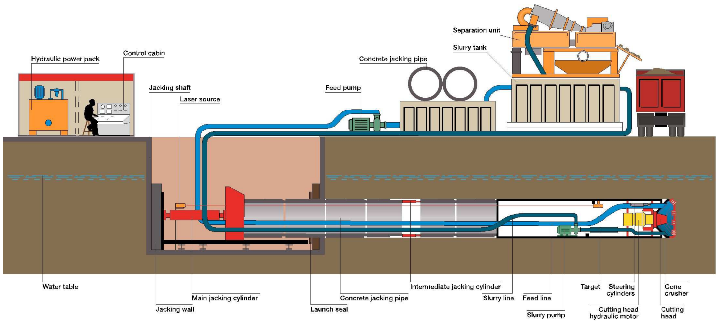

Fig. 4: Typical microtunnelling jobsite setup

MT can be applied for the pipe jacking of pipes preferentially manufactured in concrete, steel and glass fiber reinforced plastics (GRP), but it can also be used for pipes made of reinforced concrete (eventually with vitrified clay protection), steel fiber concrete, fiber cement, vitrified clay, cast basalt, steel, ductile cast iron, plastics (PE, PP, PVC). MT technology is particularly suited for the laying of casing pipes.

MT ensures an accurate construction in all ground conditions with minimal restoring requirements, thanks to the mechanical and hydraulic support offered to the front face, the constant monitoring of the microtunneller direction with a laser system and the simultaneous control of the boring and advancing parameters.

Horizontal Directional Drilling (HDD)

Horizontal Directional Drilling is defined as a steerable system for the installation of pipes, conduits, and cables in a shallow arc using a surfaced launched drilling rig. In HDD a fluid filled pilot hole is drilled and this is then enlarged by a wash over pipe and back reamer to the size required by the product. HDD method can be applied for the pulling of product pipes as well as PE and steel casing pipes.

HDD is a trenchless methodology that can be implemented with very little disruption to surface activities and may be performed more quickly than open-cut methods. HDD technique enables utility tunnels and pipelines to be laid under rivers, roads or other obstacles in a quick and inexpensive way and with minimum environmental impact. HDD can be used to install new pipelines or replace existing ones. Depending on the diameter of the pipeline to be laid and of the length of the installation to be carried out, the size of the construction site may be such as to prevent its mobilization in an urban area.

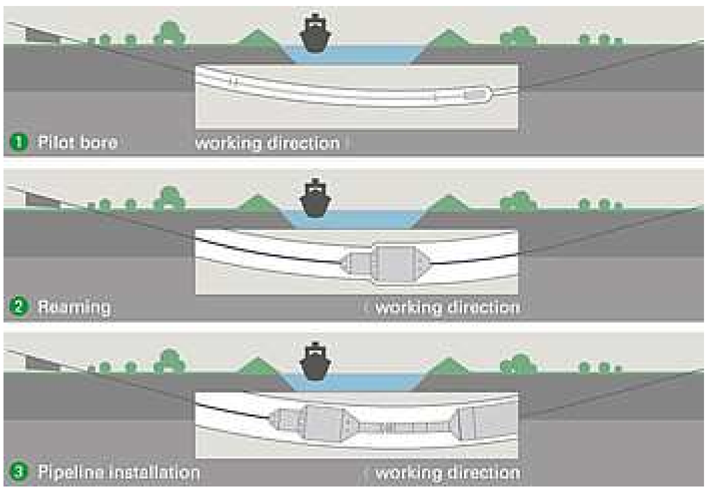

Fig. 5: Pilot drill, reaming and pipeline installation (Source: Herrenknecht)

HDD method can be applied for the pulling of product pipes as well as PE and steel casing pipes.

Direct Pipe (DP)

Direct Pipe® Herrenknecht method is a trenchless pipe-laying method, which consists in the fabrication of a subterraneous cylindrical hole in the ground by simultaneously excavation and installation of a prefabricated pipeline with allowable bending radius for the whole crossing section. It combines the advantages of the well established construction methods Microtunnelling and HDD. Unlike MT and HDD techniques, DP method allows to lay down the pipeline in one single working step without using additional protection pipes or large-volume hydraulic bore hole supporting media. In specific cases DP can be therefore used as an alternative, more efficient and cost-effective method than the MT technology.

Fig. 6: Typical direct pipe jobsite setup

DP method can be applied for the pipe jacking of product pipes as well as steel casing pipes. In the DP method large-diameter product pipe can be laid without casing pipes.

Comparison among the three methods

In the following table are highlighted the advantages of DP with respect to HDD and MT methods.

DP versus HDD	DP versus MT
One step - no reaming	No casing pipe necessary
Smaller borehole diameter	Less volume of drilled material
Permanent borehole support	One step installation
Access only one side needed	Pull back option in case of obstacles
Low risk for laying in sections with discontinuous schedule	
Low pressure drilling – no blow out risk – less coverage under river bed	
Less overburden needed	
Possibility of discontinuous working process	

Installation of product pipes in casing pipes

Concerning the piping network for STES installation using casing pipes, one of the most relevant aspects to be considered is the design of the internal layout of the product pipes inside the casing pipe. This aspect is important in order to prevent the selected product pipes from coming into contact with the casing pipe (installed using one of the three trenchless technologies previously described) during the pulled-in installation phase.

A dedicated study of this specific aspect related to product pipes installation has been performed and an innovative method to solve the problem has been identified. The proposed methodology consists in studying appropriate saddles fitted with skids, usually supported within the internal part of the casing pipe at regular distances. This solution makes easier the network piping installation and is able to solve the problem of contact among the pipes during the installation as well as the operation phase.

4. Application in a real case

All the above mentioned studies are currently used as basis for the design of the STES piping network implementation in a real case. The selected site is place in Ząbki, near to Warsaw (Poland), within the premises of the provincial hospital for nervous and mental diseases. STES will cover space heating needs in Administrative Building. The scheme of STES localization and some examples of heating network are presented in figure below.

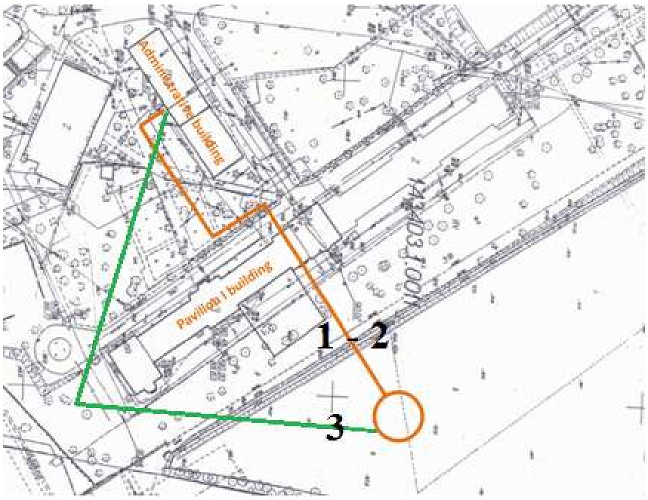

Fig. 7: Polish demo site in Ząbki (Poland), STES piping network scenarios

The aim is to use the Polish pilot as a case study to define, and consequently describe, the approach followed for identifying the most suitable trenchless technology for STES implementation in this specific site. The approach used for the Polish pilot can be generalized as guidelines for STES piping network design and implementation, to be used in any other sites with different characteristics.

The building is equipped with central, water heating systems. Gas boiler is the source of heat for space heating and DHW purposes and the temperatures of water are 80/60 °C.

In the scope of EINSTEIN project, the existing building will be equipped with Seasonal Thermal Energy Storage (STES) tank, heat pump and solar collectors. Flat plate collectors will be installed near the STES. Heat pump will be installed at the basement of the Administrative building.

A dedicated study is ongoing for the design and realization of the hydraulic piping network which connects the installed devices (STES, heat pump and solar collectors) to each other and to the interested building.

The Polish pilot plant design regarding the STES piping network is currently at a beginning phase, which consists in the definition of the most suitable perforation and piping laying down systems among the trenchless technologies previously described: MT, HDD and DP. In particular, the best solution is strongly linked to the effective piping path from the STES tank to the Administrative building. At this purpose, three different possible scenarios have been identified:

1. Piping passes below the Pavilion building basement and goes to the Administrative building
2. Piping passes through the first floor underground of the Pavilion building using an already existing window and goes to the Administrative building
3. Piping goes around the Pavilion building

An example of technical design for the specific case of solution number two (2) is reported in the figure below.

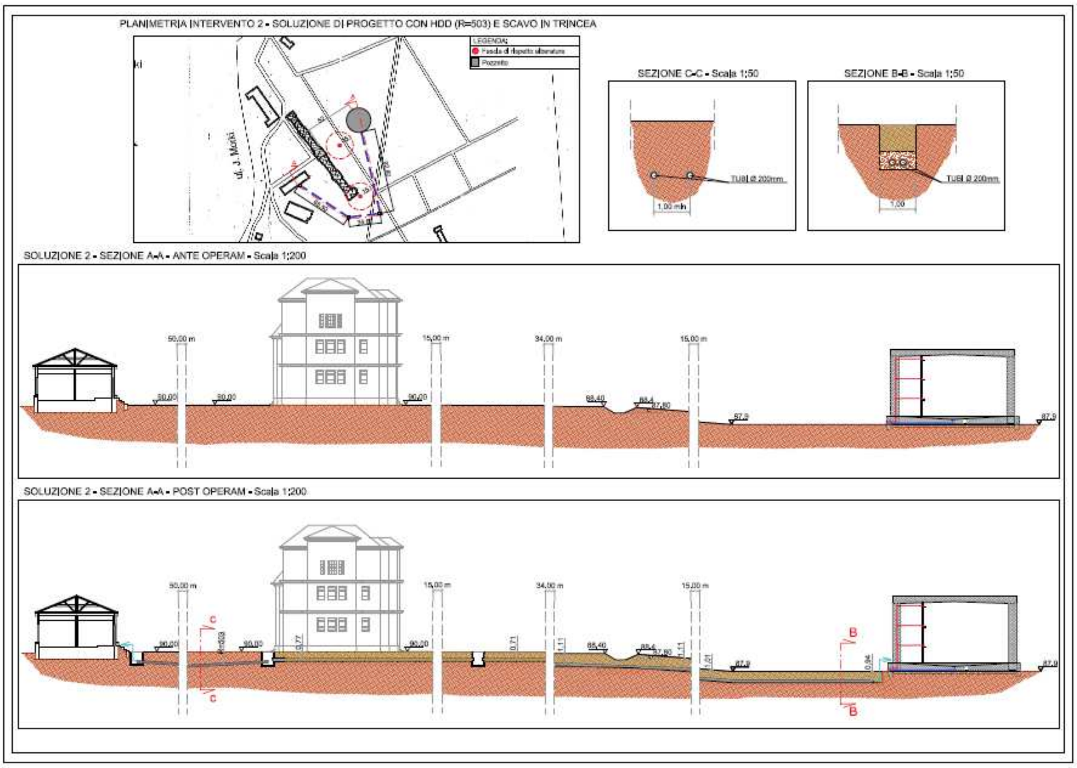

Fig. 8: Polish demo site, STES piping network scenario number two (2)

For each of the above presented scenarios a dedicated analysis of the main parameters playing a key role in the selection of the best trenchless solution (MT, HDD, DP) is currently under development. The results will be available once the construction works of the pilot plant will be finalized, by September 2014.

A specific analysis will be performed to design a special steel saddle for product pipes group installation according to the specific design requirements of the Polish pilot plant project.

5. Conclusion

The results of the analysis performed within EINSTEIN Project highlighted that the trenchless technologies constitute the most advanced and least invasive systems that can be used in a built environment to install district heating pipes. Therefore, the most innovative part of this research consists in identifying perforation and pipes installation techniques, after the definition of the product pipes technical characteristics, as well as the associated methodology, to apply them in the STES piping network implementation.

The analyzed techniques are MicroTunnelling (MT), Horizontal Direct Drilling (HDD) and Direct Pipes (DP). The use of such methods can be particularly interesting for STES installation mainly because it allows installing all the required product pipes into a unique casing pipe in a minimal invasive way. The MT technology is particularly suited for the laying of casing pipes. HDD and DP are, instead, mainly meant for the direct laying of product pipes; however, in particular cases, they can also be used for the laying of pipes meant to contain other pipes. The employment of these techniques is strongly influenced by the available areas for the construction sites and by economic considerations of convenience related to the size of the work to be carried out.

All the information included in this article starts from a state of the art analysis and has been reworked for customizing to a new application: STES piping implementation. The described perforation and piping laying down systems concur to draw up guidelines for implementing STES piping network. A specific example of trenchless technologies used for implementing hydraulic pipes is provided by the Polish pilot plan, which is in phase of design and will be developed in the coming months. Once the Polish pilot design will be further defined, the complete results of the analysis will be available. This complementary part of the work will finalize the STES piping guidelines implementation with a high added value thanks to the concrete approach based on the pilot real on-site experience, including both design and implementation project phases.

6. Acknowledgements

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